JFACC PROJECT

BAA 99-18

AGILE CONTROL OF MILITARY OPERATIONS

PROPOSER'S INFORMATION PACKAGE

March 31, 1999

Defense Advanced Research Projects Agency
Information Systems Office
3701 North Fairfax Drive
Arlington, Virginia 22203-1714

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1. Introduction

Thank you for your interest in the Joint Force Air Component Commander (JFACC) Project. The Information Systems Office (ISO) of the Defense Advanced Research Projects Agency (DARPA) is soliciting proposals (technical and cost) from qualified corporations, research centers, and universities for the JFACC Project in the area of "Agile Control of Military Operations" under BAA 99-18. We (DARPA) intend to contract with qualified sources to research and develop theoretical techniques, tools, models, and experiments that explore and advance the unique applicability of control theory and other promising technologies toward achieving real-time dynamic control of military operations. This project will specifically focus on the control of air operations. We are soliciting proposals in two categories: 1) Theoretical Techniques and Tools and 2) Air Operations Enterprise Model.

The JFACC Project aims to catalyze a revolutionary change in military command and control (C^2) of the future by tackling one of its toughest problems - the agile and stable control of distributed and dynamic military operations conducted in an uncertain and rapidly changing environment. During the previous phases of this project, we made significant progress in many of the underlying planning technologies required for efficient and effective C^2. However, we have recognized that as planning and decision cycle times are driven toward very short timelines, especially in the military air domain, agile and stable control of planned operations has become the critical challenge.

We are structuring the next few years of the JFACC Project into two phases with different technical objectives: a Design Phase and a Prototype Phase. The Design Phase will last 18 months and this BAA will be used to acquire the majority of effort during this phase. The major output of the Design Phase is a preliminary C^2 system design that incorporates the work from previous phases (Planning Techniques and Tools) and the theoretical and technical insights gained during this phase. However, a critical milestone for the Design Phase will be the summer of 2000 when a draft of the preliminary system design will be produced by our System Architect (already on contract and not a part of this BAA). This draft design will be the basis for our Prototype Phase solicitation and will rely heavily on the early work accomplished during this Design Phase. Therefore, it will be incumbent upon you to deliver your initial products in the first 10 months to support that milestone. The Prototype Phase will begin in 2001 and last

approximately 2 years. During the Prototype Phase, we will develop selected prototype software components and experimentally prove the technical and operational feasibility of our newly developed C^2 system design. A separate BAA will be issued in the latter part of 2000 for the Prototype Phase. See Section 3.1 for a more definitive description of the phases.

Key dates and milestones for this solicitation are discussed in Section 3.4. We are not conducting an Abstract review process for this solicitation. Proposals for both categories will be due by 18 May 1999, 12:00 noon Eastern Daylight Time. Contracts awarded under this BAA may be Cost-Plus-Fixed-Fee (CPFF), Grants, or Other Transaction Agreements (see Section 3.3 for further information). Proposers (You) are responsible for selecting the contract mechanism you believe to be most appropriate and explaining the rationale for your choice. The funding and number of anticipated awards for this solicitation are shown in Table 1.

Proposal Category ($M)	**FY99**	**FY00**	**Anticipated Awards**
1) Theoretical Techniques and Tools	6.2	12.0	~10-12
2) Air Operations Enterprise Model	4.5	10.0	1-2

Table 1. Funding and Anticipated Awards for BAA 99-18

On 20 April 1999 from 8:30 a.m. to approximately 12:30 p.m., we will present an unclassified informational "Briefing To Potential Proposers" covering this BAA at the Arlington Hilton Hotel (Ballston) in Arlington, VA. You should refer to Section 5.4., "Briefing to Potential Proposers" for additional information and procedures to register for this event.

This is an unrestricted solicitation. Proposals submitted shall be in accordance with this announcement. This BAA will remain open from the date of publication until the proposal due date. See Section 3.4. for specification of important dates. No portion of the BAA will be set aside for Historical Black Colleges and Universities (HBCU) or Minority Institutions (MI) due to the impracticality of reserving discrete or severable areas of research for exclusive competition among the entities. However, we encourage these entities to respond to this solicitation.

2. Project Objectives

2.1 Introduction

If we are to be successful in our endeavor to catalyze a revolutionary change in military command and control (C^2) of the future, we must scientifically study, explore, and experiment with one of its toughest problems – the agile and stable control of distributed and dynamic military operations conducted in inherently uncertain, hostile, and rapidly changing environments.

2.1.1 Operational Gaps

Today's C^2 systems for Air Operations have evolved through a number of important stages; they have undergone profound enhancements over the years based on practical experiences and technical analyses. However, in order to make a quantitative and qualitative leap in the direction of dramatically increased agility, today's systems must overcome a number of critical gaps, including:

- **Limited Agility.** The ability to rapidly and efficiently respond to varying time constraints, changeable resources, erratic hostile responses, asymmetric threats and unpredictable anomalies is an unsolved challenge. For example, current difficulties in prosecuting critical mobile targets are but one manifestation of this gap. Today's C^2 systems necessitate fairly long response times and are limited in their ability to react or act proactively, consistently and efficiently to rapid changes in environment, in opportunities, in effects of execution, or in higher-command objectives.
- **Constrained Flexibility.** Today's C^2 systems adapt poorly to the wide spectrum of military conflicts and activities that they are called upon to support. Air Operations can run the gamut from humanitarian relief to enforcement of no-fly zones to surgical strikes to full scale war, but the tools (software applications) and processes currently in-place are based on bombs-on-target warfare and cannot provide the scalability and the extensibility needed.
- **Ad Hoc Stability.** Humans are the stabilizing elements of current military operations. Management of destabilizing events, such as time critical targets, changes in guidance, or windows of opportunity, are only processed by humans with little, or no, help from decision support systems. Their C^2 systems do not offer the ability to perform rapid,

efficient changes in current operations while simultaneously taking into account the long-term effects and requirements. Nor do they take into consideration the disruptive and inefficient impacts on downstream plans and operations.

- **Ineffective Feedback.** Military operations suffer from a feedback mechanism that does not support reliable performance assessments, timely responses to information requests, consistent situational analysis, or relevant reporting factors. In other words, many decisions are made without the benefit of the disciplined incorporation of feedback on operations. Although a significant amount of feedback data, such as Battle Damage Assessment, number of sorties flown, number of targets serviced, etc., are available, the feedback does not support the commander and staff in a reliable, timely, consistent, or relevant fashion, nor at the level of abstraction and integration that allows decision makers to make effective decisions.
- **Expansive Personnel And Facility Requirements.** Today's C^2 systems rely on large numbers of highly trained personnel, making C^2 operations expensive, difficult to deploy, necessitating large physical and informational footprints, and exposing such organizations and their facilities to asymmetric threats.
- **Ineffective Use Of Assets And Resources.** In order to increase their flexibility and responsiveness, today's systems rely on the multiple use of resources, ready availability of large quantities of assets in theater, and redundancy. When a rapid change is executed, inadequate coordination between various functional activities often leads to a relatively high percentage of incorrectly planned and executed missions.

2.1.2 Agile Control of Dynamic Military Operations

Dramatic progress has been made in the last few years, in the fields of digital communications, information collection and dissemination, and automated operations planning and scheduling, to close these operational gaps, especially the latter two gaps. These improvements offer a strong basis for increasing the agility and responsiveness of military C^2 and for drastic reductions in decision cycle times. However, we recognize that as observation, orientation, decision, and execution times are driven toward progressively shorter timelines, the control of dynamic phenomena within real-time operations becomes the key challenge to

practical implementation of any new generation of C^2 systems. This key insight is the reason why the emphasis for this BAA is on theories, models, technologies, and concepts that manage the dynamic effects of large scale, highly agile command and control systems.

Our focus is the domain of Joint Air Operations (see Figure 1). This demanding C^2 domain provides researchers and developers a challenging problem area for their theories, techniques, and tools and allows them to perform focused experiments with specific applicability. However, we expect that the results of this project will be broadly applicable to multiple areas of military C^2, and will also produce significant innovations applicable to the theory and practice of commercial enterprise control.

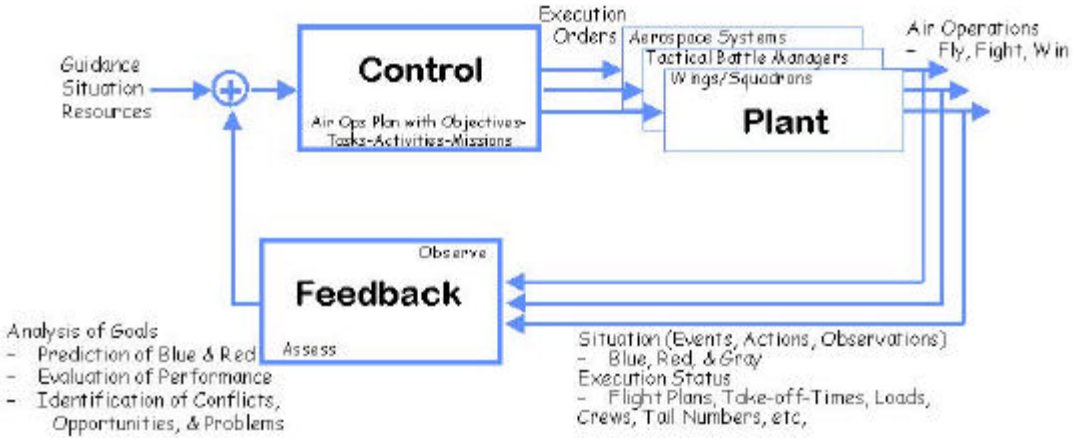

Figure 1. The Joint Air Operations Enterprise

To help orient you to the Joint Air Operations domain, we will use Figure 1 to define some terms and concepts that are used throughout this solicitation. The JFACC is in charge of all Joint Air Operations and typically performs his roles and responsibilities with an organization known as a Joint Air Operations Center (JAOC). For our purposes, the Joint Air Operations Enterprise spans the interactions with the higher and peer echelons, the activities within the JAOC, and the participation of executing forces. Starting in the upper left corner and working clockwise, the elements within the JFACC's domain are:

- Guidance, Situation, and Resources are those inputs [a continuously updated reference signal] received from higher echelons of command, typically the Commander of the Joint Task Force (CJTF) or the regional Commander-in-Chief (CINC). This guidance normally includes a description of the crisis, a statement of the objectives and end-states to be achieved, and an allocation of resources.

- The Control generates outputs, the Execution Orders [a continuously updated control signal], optimally formulated to achieve the commander's guidance. Within Control, there is an internal cycle for creating, monitoring, assessing, and modifying the control signal [plan]. The key inputs are 1) the CJTF guidance and 2) the results of analysis from the Feedback.
- Execution Orders are inputs to the elements of the Plant [action elements] providing time, location, desired effects, and other parameters to be achieved.
- The Plant performs the physical actions in the Battlespace. There are three directly controlled plant elements: 1) wings and squadrons, which provide the aerospace systems; 2) tactical battle managers (such as AWACS and ABCCC), which typically provide real-time control of airborne or on-alert flying entities; and 3) aerospace systems, which can be directly manipulated by the JAOC. Some of the indirectly controlled plant elements include 1) the adversary (in military parlance we try to "control" or shape the adversary's actions and reactions) and 2) the weather (although we don't "control" the weather we do try to control its impact and influence on both friendly and hostile actions). Alternatively, you can view the enemy and the weather factors as parts of the Plant's environment.
- Air Operations is simply the aggregate of the functions performed by the Plants.
- Situation and Status are data from a variety of sources which constitute the observations available to the Feedback.
- Feedback receives the observables and interprets, collates, fuses, and analyzes them to provide an assessment [error signal] that describes the deviations between the desired state-of-the-world and the state inferred [state estimation] from the observations. In essence, assessment is the extent to which CJTF guidance has been or will be achieved.
- Analysis of Goals is the result of the assessment [error signal].

Finally, we think of the JFACC System as a suite of tools and applications (a software architecture) and the decision makers that perform the functions necessary to manage Joint Air Operations in a flexible, efficient, effective, and responsive manner.

2.1.3 Intended End-State of the Project

To achieve this kind of agile control, we see the need for experimental studies, technical insight, theoretical underpinnings, and technology development in the arena of dynamic behavior of the control mechanisms that will underlie future agile and stable military C^2 structures. Even though any individual process within the current C^2 systems can be made more efficient, effective and responsive using available results of the information revolution, the overall systemic effects are expected to present formidable, complex challenges characteristic of large scale, dynamic control systems. These challenges will be addressed by the products and results of the JFACC project. We expect to accomplish the following during the Design Phase:

- Develop and experiment with theories, principles, models and techniques of agile and stable military control. Construction of new architectures and component technologies will require extensions or developments in theories, models and techniques that address the technical challenges of the military C^2 problem. This work will be done under the Theoretical Techniques and Tools category of BAA 99-18.
- Spawn an Air Operations Enterprise Model that fosters, encourages, and enables the exploration and experimentation of the dynamic phenomena of real-time, agile control of military operations. This work will be done under the Air Operations Enterprise Model category of BAA 99-18.
- Exercise the Air Operations Enterprise Model and generate new architectures for military C^2. Generation and evaluation of novel architectural concepts of military C^2 (which include all the functional and information systems considerations) will require significant experimentation. These experiments should address the theoretical, functional, and systemic issues of dynamic behavior in agile enterprise control. This work will be done by the System Architect during the Design Phase.

During the Prototype Phase, we will apply the theoretical and technical discoveries and achievements, from the Design Phase, to the functional requirements to accomplish the following:

- Build selected prototype components. To construct the experimental “breadboard” system, prototypes of key components will be designed and constructed. Component-

based experiments will be performed to determine critical characteristics of individual components prior to system-wide experiments. The prototype components will:

- Enable experiments. These components, while not always directly applicable to operational use, will enable execution of systemic experiments.
- Prove technology feasibility. Components will embody and demonstrate the feasibility of a number of novel technical approaches. Construction of these components and execution of component-based experiments will provide insights into feasibility and requirements of key technologies necessary to construct an overall C^2 system with operational value

- Experimentally prove the operational and technical feasibility of revolutionary advancements in agile military C^2. An experimental system will be constructed to reflect key aspects of the new C^2 concepts. Series of experiments will be conducted to answer the questions of both a technical and operational nature.

2.1.4 Preliminary System Design

As discussed earlier, the ultimate goal for this Design Phase is a preliminary system design that will provide the basis for a revolutionary way of conducting military C^2. The System Architect will be responsible for developing the system design, using work done in previous phases and incorporating the insights and technologies developed during the Design Phase. A draft of this new design will be due by the Summer of 2000 as a basis for the Prototype Phase solicitation.

The System Architect will develop the architecture and the system design specification that will enable rapid and focused development of the experimental "breadboard" system in the Prototype Phase of the JFACC project. To accomplish this, they will cooperate with researchers and the Enterprise model developers to collect, organize and integrate multiple ideas, principles, concepts, model-based experiments and previous JFACC work into several promising functional system architectures. They will be exercising the Enterprise Model(s) to objectively observe and analyze the various phenomena and characteristics and to incorporate their analyses into their design work. Then, for each of the several selected architectures a detailed functional system design specification will be developed.

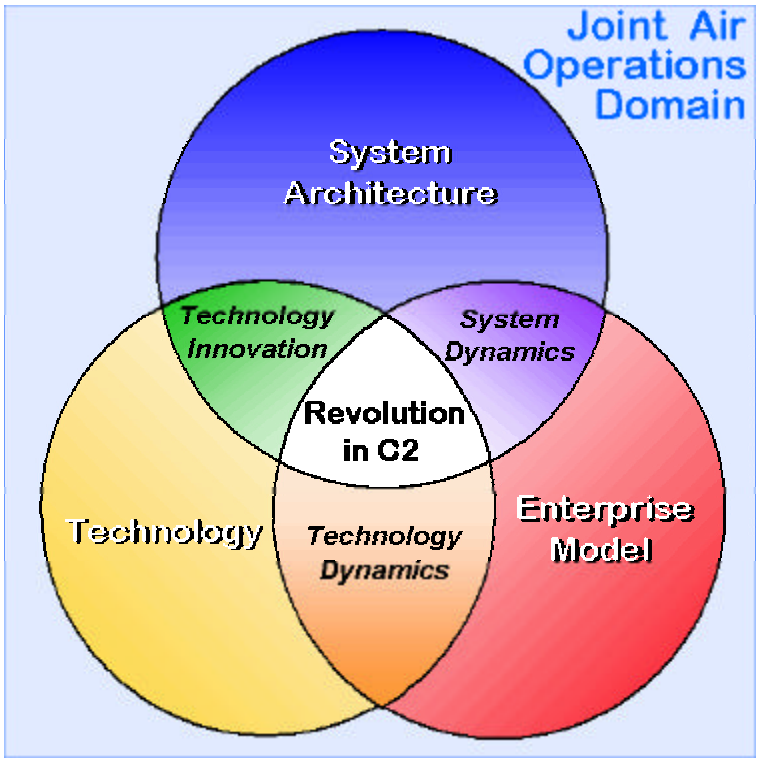

Figure 2. The JFACC Project Design Phase Concept

2.1.5 Team Spirit

This will be a team-oriented project. As you read this proposal and begin to understand our vision for a revolution in military C^2, you will see that no one idea or concept, no one technology or theory, no one technique or tool, and no one business process model will yield the dramatic results that we are striving for. We fully expect all players on the JFACC development team – government, incumbent contractors, and new contractors – to be partners in this journey

of exploration and discovery. Open communications and shared ideas are absolutely required. The System Architect and the developers in the two categories (described below) must have a strong, interactive relationship as shown in Figure 2.

2.2 Category 1 – Theoretical Techniques & Tools

In general, there is very limited understanding of the potential effects of automation on the dynamics of an enterprise control system as complex as military C^2. History offers many examples where the introduction of automation, and particularly introduction of a feedback loop, caused complex, counterintuitive, and unexpected dynamic phenomena. Introduction of automated supervisory control in manufacturing, chemical and power plants has routinely yielded such puzzling behaviors and caused extensive rework of the control systems to obtain adequate operational behavior. There is also anecdotal evidence that recent attempts to shorten the military decision cycle via computerization can cause undesirable dynamic effects, such as uncontrolled oscillations.

More specifically, there is a lack of theories, models, tools, technologies, and technology components that support substantially automated control of large-scale, distributed, dynamic, systems operating in uncertain, rapidly changing and hostile environments. Research literature on problems of this nature is rather sparse.

2.2.1 Areas of Interest

A key effort solicited under this BAA is the development of innovative theories, techniques and tools that will support and pioneer the control of large-scale, distributed, dynamic, military operations in uncertain, rapidly changing and hostile environments. We are interested in proposals that address novel theoretical developments with applicability in the Joint Air Operations domain in one or more of the following interest areas:

a) Distributed Control. This includes approaches to disciplined rigorous application of principles and techniques of distributed control to the problem of military C^2 with its characteristic complexities: extreme dynamics, changing structure of the system itself, inherent uncertainty and hostile actions of the adversary. Of particular interest are techniques for determining effective distribution schemes and techniques for analysis and synthesis of distributed control architectures tailored to the characteristics of the plant and environment.

b) Human-Embedded Systems. Regardless of extensive computerization, humans will remain critical decision-making elements in military C^2 systems of the future. There has been limited work on modeling humans within control systems, and on synthesizing control systems that match the strengths and limitations of human performance. We are interested in models of the effects produced by the humans (and **on** the humans) who act as elements of mixed, human-machine control systems; in techniques for modeling human performance in such systems; in analysis and synthesis techniques for systems with embedded humans; and in principles of design that assure that humans remain in control of their highly automated environments and are able to maximize their performance and unique skills within such environments.

c) Symbolic Control. Although work done on model-predictive control of manufacturing plants appears relevant, it is recognized that most of the experience to date has been with continuous systems, while military C^2 is seen largely as a preponderance of discrete, symbolic variables. The control signals of military C^2 are complex, time-phased orders that bear little resemblance to the continuous variables studied in classical control theory. A military C^2 system relies primarily on the exchange of symbolic information, with some inclusion of continuous variables. Theories and techniques for analysis and synthesis of such symbolic and hybrid control systems have been studied to a limited extent and only in the last few years. We are interested in theoretical advances that will enable practical analysis, synthesis and modeling of such hybrid systems, with particular reference to systems with changing structures, high uncertainty, and hostile elements.

d) Dynamically Changing "Plant" And Online System Identification. In our current way of thinking, the "plant" of the military C^2 system includes friendly forces that execute the missions and achieve desired effects on the adversary. During military operations, these plants are continuously changing spatially and structurally. These plants reflect a continuously changing system – plants move in space, they move in and out of the theater of operations, they change their composition and command structure, they are attrited over time and may get reconstituted, they consume and exhaust their physical resources and change their capabilities over time. Significantly more research is needed on control of such large-scale time-varying plants, including abrupt structural changes. Applications that share some of these features include control of electric power grids,

transportation systems, and communication networks. It also requires techniques and tools for dynamic, on-line estimation of system parameters while accommodating changes to the system model.

e) Hostile Counteractions. A major and unique aspect of controlling military operations that differentiates it from, for example, a manufacturing enterprise control, is the presence and critical influence of an actively counteracting adversary. Unlike a random disturbance from environmental factors such as weather, and unlike a random disruption within the "plant" such as equipment breakdown or a personnel error, the actions of the adversary are intentional and designed to cause the friendly entities as much harm as possible at the time and place where it will be most effective. These hostile actions are dependent on the capability and plans of the adversary as well as on the adversary's perception of the intent of the friendly forces. There has been little work done on control in the presence of entities that actively and intelligently disrupt and attack the actions of the controller. Modeling, analysis, and synthesis of such systems requires new approaches. Rolling horizon control is one well studied technique but most experience has been with small, gradual changes, unlike the rapid and substantial changes seen in military operations.

f) State Estimation. State estimation in a military C^2 system also presents unique challenges. The sensor data are inherently uncertain and incomplete, being affected by the nature of the environment and also by the intentional actions of the adversary intended to deceive and confuse the friendly information collectors. The volume of observed data and the rate of change is extremely high, however only a fraction of the available data are actually relevant at any given time. Therefore, the placement of sensors, and the importance of the available data must be dynamically determined and frequently changed depending on the situation. Much of the control actions often depends on a pattern of observed data that may emerge anywhere and anytime and may not be apriori predicted. The state of the system includes determination of friendly characteristics as well as those of the adversary. Given these challenges, we are interested in techniques and tools able to perform state estimation in such environment, including (a) dynamically determining the data that are important to observe or monitor,

when and where; (b) deriving the system in the face of highly uncertain and potentially deceptive observations from a plant that can undergo abrupt, unknown structural changes.

g) Other, As Submitted By Proposers. We recognize that we may not have identified or adequately categorized all the possible areas of control theory or other theoretical domains which are applicable. There are other theories and technologies, such as complexity theory, complex adaptive systems, biologically-based models, and more, which may have applicability to this project. We welcome and encourage your succinct and well organized approaches, ideas, or techniques which would support our basic premise of enabling agile and stable control of military operations.

2.2.2 Products:

The products of the proposed efforts should include some or all of the following:

- Techniques and tools, both theoretical and functional,
- Experiments that verify the proposed techniques or predicted phenomena and employ viable measures of merit and effectiveness,
- Analytical models of key system elements and phenomena,
- Theoretical analysis of the proposed new techniques and approaches,
- Identification, prediction and characterization of potential undesirable patterns of dynamic behaviors that are likely to occur in a military C^2 system, their sources and quantifiable characteristics,
- Research prototype software that implements a technique or a model and allows experiments in support of the theoretical predictions and can support transition to software components in the Prototype Phase,
- Tools, such as software programs, that allow the enterprise model to perform the proposed analyses or syntheses,
- Papers presenting rigorous formulations of the problems.

2.3 Category 2 - Air Operations Enterprise Model

The dynamic phenomena associated with the control of military operations have not been studied. To a very limited extent there have been a few attempts at building process models focused on data flow issues and connectivity requirements, but dynamic models of the Air Operations domain do not exist. The other key effort solicited under this BAA is the development of a model of the Joint Air Operations Enterprise. Our intent for the model is to enable, conduct, and analyze experiments that would provide insights into possible dynamic phenomena; verify the value or contribution of various theoretical techniques and tools that will be developed under the other solicitation category; and identify the qualitative and quantitative characteristics of required functional component technologies. These experiments will test the techniques and tools both singly and together. The Enterprise model is not the solution to creating a revolution in military C^2 , but it will be an important tool for generating and testing the overall system design .

2.3.1 Air Operations Enterprise Model Requirements

We invite proposals to construct an Enterprise model of the Joint Air Operations domain with the desired characteristics, functionality, scope, and utility outlined below:

- **Create An Enterprise Model.** The Enterprise Model will include models of friendly systems and organizations that control and execute air operations. These models must be implemented in such a manner as to allow them to be organized in several alternative structures corresponding to the various conceptual and architectural models that might be tested and analyzed. The Enterprise Model will also include models of adversary systems and organizations that execute their own operations to disrupt or counteract the friendly actions.
- **Prescriptive and Descriptive Modeling.** The primary focus of this modeling effort will be on prescriptive modeling of the Enterprise organized in concert with the innovative techniques and tools being developed. However, a fraction of the effort will also be dedicated to supporting the descriptive modeling of the current Joint Air Operations. The purpose of this supporting effort is to verify the fidelity of the modeling approach by simulating the command and control phenomena actually observed in past and current military operations or exercises. The Air Operations Enterprise Model will be used to:

- simulate the dynamic phenomena in the enterprise, such as instability, overshoots, excessive delays, etc. under different assumptions and conditions;
- explore different concepts of the enterprise organizations, hierarchy, and distribution of authority;
- experiment with different control strategies, laws, and theories;
- answer questions for the Theoretical Techniques and Tools developers regarding simplifications, generalizations, assumptions, and other parameters of different parts of the enterprise; and
- provide a flexible, reorganizable, and robust framework to try different combinations and configurations.

- **Scope of the Model.** The model will cover the hierarchy of military operations and C^2 starting at the Joint Task Force or CINC level, through the JFACC level, down to the wing level and progressing through the squadron level, the tactical battle manager's level, and finally to the aerospace systems themselves. The model should include:
  - the inputs/outputs to higher echelons, peer echelons and other supporting or supported elements (to include intelligence support);
  - the employment dynamics of preparing aerospace systems for flight, to include personnel, fuel, payloads, and other parameters;
  - the time and spatial dynamics of the sorties, but not the classic air battle models of air-to-air engagements, ground-to-air threats, or weapons effects;
  - the flight recovery dynamics of observation and feedback.
  - the decision making actions of planning, assessment, and execution;
  - the adversary entities, such as air and ground operations, targets, and air defense systems at an abstraction level sufficient to experiment with the dynamic phenomena of adversary actions;
  - the tactical battle control entities and information/intelligence collection systems;
  - the inputs/outputs to/from the friendly entities executing ground and maritime operations, to the extent that such inputs/outputs affect the air operations, but not the ground and maritime operations;

- the inputs/outputs to/from the friendly entities executing force support, to the extent that such inputs/outputs affect the air operations, but not the logistics operations themselves.

- **Supports Experimentation.** The developers of the Enterprise model will be responsible for supporting the researchers who develop new theories and techniques. These developers will implement, within the model, a number of selected theoretical constructs or phenomena in cooperation with theory researchers and will help design and execute experiments to provide feedback to the researchers that evaluates the theoretically predicted behaviors. Finally, the developers of the Enterprise Model will be responsible for supporting the System Architect and a variety of experiments to optimize the system architecture and design parameters.

2.3.2 Products

The developers of the Enterprise models will produce the following products:

- Software code that implements the model, along with the modeling tool or environment that is used to execute the model code,
- Documentation to support the employment and use of the Enterprise Models,
- Support to the researchers who develop new theories and techniques by providing, supporting, and operating a test bed for analysis of the theoretical work.
- Support to the System Architect who develops new architectural concepts, designs and system models of the objective C^2 system.
- Capability to support a number of selected architectural constructs and in cooperation and under the guidance of the System Architect, design, execute and analyze experiments with the model as requested by the System Architect.

3. Acquisition Strategy

3.1 Acquisition Approach

As discussed earlier, we are structuring the next few years of the JFACC Project into two distinct phases – a Design Phase (lasting 18 months) and a Prototype Phase (lasting approximately 24 months—see Figure 3). These are not mutually exclusive phases, in that products from the Design Phase and earlier phases will be integral parts of the Prototype Phase. To help ensure that we have techniques, tools, and models available for the draft preliminary system design (due the summer of 2000), we are asking for initial products within 10 months of contract award.

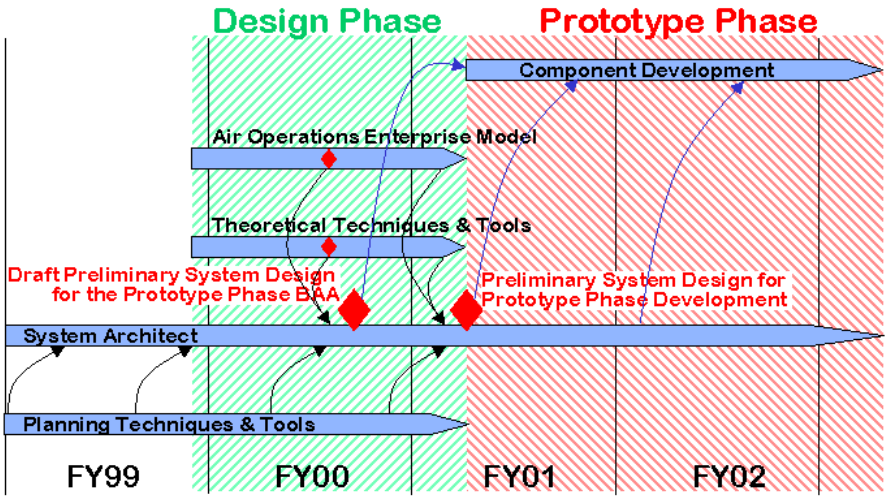

Figure 3. JFACC Project Phase Schedule

3.1.1 Theoretical Techniques and Tools

We intend to award 10-12 contracts for the seven (7) interest areas in this category as described in Section 2.2.1. We recognize that there may be some synergistic or holistic value to combining or converging several of the interest areas. Therefore, you may bid against any combination of the seven interest areas. We also recognize that some of you may have a very unique and focused capability to offer. We encourage you to bid against single interest areas as well. We intend to pursue multiple approaches to each interest area.

3.1.2 Air Operations Enterprise Model

We intend to award up to two contracts in this category. The Air Operations Enterprise Model will serve as the heart of our detailed analysis approach for our preliminary system design solutions, so we plan to mitigate our risk by offering multiple awards. This also offers us the opportunity to pursue two different approaches to the modeling problem. We also envision that

it may become a key component of the new design, therefore, selected efforts may be extended into the Prototype Phase.

3.2 Constraints

There are no constraints to bidding in either category. You may submit a proposal and be awarded a contract in both categories. If you are selected for both, we intend to combine the efforts into a single contract with separate tasks.

3.3 Contracting Vehicle

Contracts awarded under this BAA may be Cost-Plus-Fixed-Fee (CPFF), Grants, or Other Transaction Agreements. Where appropriate, we encourage you to consider the use of Other Transaction Agreements (see the following documents for further information: http://www.darpa.mil/cmd/pages/other_trans.html, http://www.darpa.mil/cmd/pages/acqconf.html, and http://www.darpa.mil/d1793/appd.html).You are responsible for selecting the contract mechanism you believe to be most appropriate and explaining the rationale for your choice.

3.4 Basis for Awards

The selection of source(s) for award will be based on an evaluation of your response to determine the overall merit of your proposal in response to this announcement. Technical and cost aspects will be evaluated. We will evaluate each technical proposal against the four criteria described below. Cost, a fifth evaluation criterion, will be of less importance than the technical criteria. No other evaluation criteria will be used. Your technical and cost information will be evaluated at the same time. You are responsible for selecting the contracting mechanism you believe to be most appropriate.

3.4.1 Innovation and Payoff

- Innovative – degree to which your proposed ideas and concepts are unique, original, and inventive (not constrained to legacy military concepts) or represent a revolutionary adaptation of technologies from another domain.
- Performance Improvements –

  - For the Theoretical Techniques and Tools—magnitude of your hypothetical or theoretical gains in control, stability, flexibility, and other performance attributes.
  - For the Enterprise Modelers – magnitude of your hypothetical or theoretical gains in model accuracy, performance, and representation.
- Risk versus Benefit – soundness of your tradeoff analyses balancing technical risks against operational improvements.

3.4.2 Technical Approach

- Problem Formulation – accuracy of your description of the problem space .
- Depth and Breadth of Understanding – thoroughness of your tradeoff analysis supporting your choice of approach.
- Measures of Effectiveness – viability of your methodology and choice of indicators for measuring progress and improvement.
- Experiment Definition – completeness of your experiments (description, hypothesis, support requirements, evaluation criteria, etc.).
- Expected Value – expected maturity and utility of your effort by the end of this procurement phase to support design definition and subsequent prototype development. Also, expected operational merit in the future.
- Commercial Baseline – extent to which consideration was given to the use of COTS or other existing products.

3.4.3 Experience and Qualifications

- Key Personnel – level of experience and qualifications of your key personnel.
- Non-key Personnel - level of experience and qualifications of your non-key personnel.
- Previous Technological Success – indications of your capabilities in this technological area. You may attach copies of published works in this area (maximum of 2).
- Previous Project Success – descriptions of your previous endeavors of comparable approach, complexity, and size, to include commercialization or transition to fielded systems.

3.4.4 Project Plan and Schedule

- Statement of Work – quality and completeness of your proposed Statement of Work.
- Proposed Plan and Schedule – soundness and comprehensiveness of your work breakdown, milestones, and deliverables.
- Risk – inclusiveness of your risk factors and sensibility of your mitigation processes and strategy.
- Team Player – proof of your willingness to be a team player, cooperating and coordinating with other performers under this Project.

3.4.5 Cost

- Realism – Reasonableness and completeness of cost estimates.

3.5 Key Milestones and Dates

Table 2 summarizes the important dates for BAA 99-18.

Milestones	Date
BAA 99-18 Published	2 Apr 1999 (Fri)
PIP Posted	2 Apr 1999 (Fri)
Briefing to Potential Proposers	20 Apr 1999 (Tue)
Proposals Due	18 May 1999 @ 12:00 noon (Tue)
Oral Presentation or Demo	24 May – 4 June 1999
Source Selection Complete	18 Jun 1999 (Fri)
Awards	Aug 1999 (as quickly as possible)

Table 2. Key Milestones and Dates

Explanation of key milestones and dates are provided below:

- 2 Apr 1999 – PIP Posted. We will post the Proposer's Information Package (PIP) online at the website specified in Section 5.2., "Proposal Information Repository." This will

also be the first day that we start responding to questions and posting them to the frequently asked questions (FAQ) file on the website.

- 20 April 1999 – Briefing to Potential Proposers. We will present an unclassified informational "Briefing To Potential Proposers" covering BAA 99-18 from 8:30 a.m. to 12:30 p.m. at the Arlington Hilton Hotel (Ballston) in Arlington VA. You should refer to Section 5.4., "Briefing to Potential Proposers" for additional information and procedures to register for this event.
- 12 May 1999 – FAQ Closes. This is the last opportunity for you to submit electronic mail questions prior to the proposal date. We will post all answers to the FAQ file by 14 May 1999.
- 18 May 1999 – Proposals Due. Your proposals are due in the DARPA mailroom by 12:00 noon Eastern Daylight Time. Complete Technical and Cost Volumes are required. Any proposals received after this date will not be considered for award.
- 24 May – 4 June 1999 –Oral Presentations and Software Demonstrations. You may be asked to provide an oral presentation of your proposal or demonstrate relevant software tools during this period. This may be a remote event, such as a video- or data-teleconference. We will provide you with sufficient notification if a presentation is desired.
- 18 June 1999 – Source Selection Complete. You will receive written notification from us regarding proposal selection. Contracting activities will commence immediately thereafter.
- August 1999 – Awards. We anticipate contracts being awarded during this period.

4. Proposal Preparation

This Section details the required submission formats for proposals under BAA 99-18. This Section also details the deliverables required as well as general submission requirements applicable to all offerors under this BAA.

Technical proposals and cost proposals, each submitted in separate volumes, are required and must be valid for 180 days. Each BAA submittal must be a single volume, and an original, ten hard copies, and an electronic copy formatted in Microsoft Word 97, on floppy or Zip disk,

of each must be submitted for evaluation. You are advised that only contracting officers are legally authorized to contractually bind or otherwise commit the Government.

DARPA may also request that selected proposers provide an oral presentation of their proposal and a demonstration of any relevant software tools.

DARPA will engage the services of non-Government technical advisors from Logica, Inc., MITRE, Corp., Softpro, Inc., and SM&A, Corp. These organizations have signed non-disclosure agreements and are ineligible to participate in this BAA. Therefore, you should apply the restrictive notice prescribed in the provision at FAR 52.215-12, Restriction on Disclosure and Use of Data, to trade secrets or privileged commercial and financial information contained in their proposals.

Proposal questions should be directed , via email, to baa99-18@darpa.mil as described in Section 5.3.

4.1 Proposal Format

This Section describes structure and formatting requirements for proposals submitted under this BAA. Each proposal shall consist of separate Cost and Technical Volumes. Format specifications include 12 point or larger type, 1.5 line spacing, single-sided, on 8.5 by 11 inch paper with 1.0 inch margins all around the page. Technical proposals shall be limited to a total of forty (40) or fewer pages (including cover page, charts, figures and tables yet excluding copies of published works [2 max]). Technical proposals in excess of this limitation may be eliminated from evaluation. Cost proposals have no page limitations; however, you are requested to keep cost proposals down to twenty-five (25) pages as a goal.

4.1.1 Cover Page

Proposals must contain a Cover Page that includes the following:

- BAA Number
- Proposal Title
- Proposal Category: Only 1 (one) of the following:
  - Theoretical Techniques and Tools
  - Air Operations Enterprise Model
- Interest Area (if applicable): One or more of the following:
  - Distributed Control

  - Human Embedded Systems
  - Symbolic Control
  - Dynamic Plant & Online System Identification
  - Hostile Counteractions
  - State Estimation
  - Other (provide title)
- Organization
- Technical and administrative points of contact, including:
  - Mailing addresses
  - Telephone numbers
  - Facsimile telephone numbers
  - Electronic mail addresses, if available
- Subcontractors and Consultants in order of anticipated contract value)
- Type of Business (Large, Small Disadvantaged, Other Small Business, HBCU, MI, Educational, Non-Profit)
- Proposals containing data that are not to be disclosed to the public for any purpose or used by the Government except for evaluation purposes shall include the following statement on their cover page:

"The proposal or quotation includes data that shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed - in whole or in part - for any purpose other than to evaluate this proposal or quotation. If, however, a contract is awarded to this offeror or quoter as a result of - or in connection with - the submission of this data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the resulting contract. This restriction does not limit the Government's right to use information contained in this data if it is obtained from another source without restriction. The data subject to this restriction are contained in sheets marked 'Proprietary' or that contain the legend prescribed by FAR 52.215-12."

Each restricted data sheet should be marked either "Proprietary" or as follows per FAR 52.215-12:

" Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation."

4.1.2 Technical Volume

Each Technical Volume of the Proposal must be a single volume. The Technical Volume provides the detailed discussion of the proposed work necessary to enable an in-depth review of

the specific technical and managerial approaches proposed. Specific attention must be given to addressing both risk and payoff of the proposed work that make it desirable to us.

You should include content in this volume addressing the evaluation criteria specified in section 3.4., "Basis for Award". This volume will consist of the following four sections:

Innovation and Payoff. This section should describe:

- Innovative claims for the proposed research, including concept of operations, state-of-the-art assessment and evaluation approach for the proposed development. You should describe the unique proposed contribution your theoretical effort will make in this problem space, i.e. what parameter(s) of agility, stability, distribution, uncertainty, etc. will be influenced and how. Model developers should, at a minimum, highlight how your model will address some of the classic issues of hybrid representations.
- Deliverables associated with the proposed research. Include in this section all proprietary claims to results that support or are part of the proposed research effort. If there are proprietary claims, state clearly their effects on your ability to deliver innovative algorithms and prototype systems to the government as part of the effort. If there are no proprietary claims, this should be stated.

Technical Approach. This section should describe:

- Your understanding of the proposed problem area and your specific technical approach, technical rationale, evaluation approach, and strategy for accomplishment of technical goals in support of deliverable product. Care should be taken to ensure that the technical discussion in this section is substantive. Up to two (2) published articles may be attached to your proposal (not included in the page count). For the theoretical efforts, you should have a solid hypothesis and rationale for why you believe that your approach will yield success (agility, stability, responsiveness, etc.) in this environment. For the enterprise modelers, you should address how you plan to offer the flexibility, robustness, and measurement capabilities needed to optimize the utility of the model.
- The analysis, engineering, management and other methodologies central to the lifecycle definition, implementation and refinement of your proposed technical solution. You should demonstrate a thorough understanding and specific techniques

for making operational and technical assessments and tradeoffs, managing design and development complexity, and incremental and iterative evaluation and evolution. Textbook processes are not desired, rather processes based on real world experience and insight into the dynamics of high risk/high payoff advanced R&D are sought.

- Your approach to experimentation to include the challenges in defining, conducting, and drawing conclusions from both operational and technical experiments. In addition, possible critical enabling technologies that could support experiment integration should be presented. You should also specifically present processes for planning and implementation of both operational and technical experiments involving single and collective behavior, metrics definition and measurement, and requirement for knowledge acquisition with military subject matter experts.

Experience and Qualifications. This section should describe:

- Key Personnel. All proposals will contain a Key Personnel clause. You should identify Key Personnel in your proposal. Key Personnel may be changed only upon approval by DARPA. The contractor may request, in writing, a change to a designated Key Personnel member by proposing a person of equal or greater experience and expertise for the specific task. No such request can be made in the first 180 days of the contract for reasons other than unavailability of the employee due to death, illness, disability, or having left the contractor's employ. Key personnel are the Principal Investigator and at least one (1) technical investigator (to be proposed by name, functional title, responsibilities, and percentage commitment). For the theoretical efforts, the JFACC Program Office will facilitate access to domain experts. Thus, it is not necessary for you to have domain experts on staff. For the modelers, we expect you to provide your own domain experts and expect to see domain qualifications or your approach to acquiring that knowledge.
- Your previous successes, accomplishments and efforts that contribute to your experience, along with a discussion of their relevance to the JFACC Project. Up to two (2) published articles may be attached to your proposal (not included in the page count).

- The nature of this project requires close interaction with multiple contractors and government entities. Therefore, your successes in working in multi-contractor environments will be an important evaluation parameter.
- Any related software prototypes that could be available for demonstration to the Government.

Project Plan and Schedule. This section should describe:

- Statement of Work (SOW) and Draft Program Plan. A SOW should be provided, written in plain English, clearly defining the scope of the effort, identifying specific tasks to be performed, deliverables to be provided, and specific contractor requirements. A Draft Program Plan should be provided for 18 months and should show initial products being due in 9-10 months. This section should also include:
  - A PERT network or Gantt chart that displays all major tasks with schedule, dependency relationships, and lead performing organization (as appropriate) clearly shown.
  - A narrative compilation with entries for each task as follows:
    - A short (1-2 sentence) description of the task.
    - Identification of organization responsible for execution of each task.
    - The resources allocated to each task (funds, man-months and duration).
    - The exit criteria for each task. These are the products or events that define completion of the task.
    - A spending plan shown as a total program cumulative cost per month in graph form.
- Your understanding of the critical complexity, uncertainty, risk, and cost drivers that are likely to impact the proposed effort. Specific mitigation strategies should be presented to address these drivers. You should also provide a defense of the cost proposal to the extent that it reflects your understanding and strategy for complexity, uncertainty, risk, and cost management.

4.1.3 Cost Volume

The accompanying Cost Volume of the Proposal shall contain a cover sheet or SF1411 with supporting schedules, and shall contain a man-hour breakdown per task per fiscal year, covering a period of performance of 18 months. Each Cost Volume of the Proposal must be a single volume. Cost proposals have no page limitation; however, you are requested not to exceed 25 pages. The Cost Volume shall include, but not be limited to, an analysis of materials, labor, travel, other direct costs and proposed profit rates.

It is recognized that you may have ideas that require funding beyond that currently available. You are encouraged to propose optional tasks for implementation if funds become available beyond those currently planned.

Subcontractors' proposals must be similarly structured. All subcontracted work must be properly identified as such. Prime contractors must provide a price analysis of the proposed subcontract in accordance with FAR 15.805-2, as appropriate.

4.2 Program Deliverables

This section details the deliverable items expected during the performance of work under this BAA.

4.2.1 Experiments

Theoretical, analytical, and/or functional experiments will be required of all participants. Experiments will be performed singly for Theoretical Techniques and Tools; in concert with the Air Operations Enterprise Model; and in coordination with other Techniques and Tools, as appropriate. All experiments will contain meaningful metrics and measures of effectiveness and performance.

4.2.2 Experiment Plan.

The plans for testing (including the test environment and schedules); metrics and measures of effectiveness and performance; test cases for the techniques, tools, and models; and respective test procedures, to determine algorithm/model performance will be provided. Also, the results of the testing will be delivered as required.

4.2.3 Scientific and Technical Reports.

Drafts of the Final Report will be due 10 months after Contract award with the Final Report being due by the end of the performance period. Interim drafts of selected sections or topics may be required throughout the period of performance.

4.2.4 Status Reports.

Reporting of technical plans, progress, issues, and funding and man-hour expenditures will be provided informally on a monthly basis, via e-mail to the COR and the DARPA project office. Summary reports will be required in hardcopy on a quarterly basis. Quarterly reports may also be part of an oral presentation given at periodic program reviews.

4.2.5 Software Items.

All software and supporting engineering and technical documentation developed under or used in conjunction with activities funded under this BAA will become government property. The supporting engineering and technical documentation will be continuously updated throughout the project duration to capture designs, design decisions, algorithm formulations, program technical progress, etc.

4.3 General Requirements

This section describes other requirements that may affect your cost, schedule, and performance analyses.

4.3.1 Project Coordination Meetings.

We are very interested in understanding and developing techniques and tools that will revolutionize military command and control. This cannot be done through individual, segregated technical efforts, but requires periodic interchanges for brain storming, conflict resolution, global optimization, and shared learning. To this end, coordination meetings will be held throughout the period of performance at a variety of locations to be specified at a later date. These meetings will include, but not be limited to the following:

- Kick-off Meeting (1-2 days long). Held shortly after contracts are awarded to impart a common vision of the project to all participants and to initiate the sharing of ideas.

- Quarterly Program Reviews (~2 days long). Held quarterly to review progress, plans, and issues. These will be hosted by the project office or other government agent.
- Knowledge Acquisition Workshops (2-3 days long). Structured interviews and dialogues with domain experts to provide participants with details about the problem space. Held aperiodically, as required. These will be organized and facilitated by the project office.
- Technical Interchanges (1-3 days long). Technically oriented meetings between two or more participants to discuss technology issues, progress, and concerns that are common to both or all. Held aperiodically, as required. These will be organized and facilitated by the System Architect (Logica).

4.3.2 Rights

We desire unlimited rights to all products delivered under this effort (government purpose rights as a minimum). If there are proprietary claims to some portion of the products, you must state clearly those components or aspects of the proposed deliverables that have limited rights, what limitations are imposed, and their effects on your ability to deliver algorithms, models or coded versions of these to the Government. You need to understand that the techniques and tools developed under this BAA will be used by the Air Operations Enterprise Model, the System Architect, and the Prototype Phase developers to create functional software and must therefore be unencumbered.

You should apply the restrictive notice prescribed in the provision at FAR 52.215-12, Restriction on Disclosure and Use of Data, to trade secrets or privileged commercial and financial information contained in your proposals.

4.3.3 Security

The generation and use of classified material for these efforts is authorized only on equipment contained within suitably secure facilities as determined by the Defense Investigative Service. The Theoretical Techniques and Tools contractors are not required to have a DOD SECRET clearance. A DOD SECRET clearance is not expected to be required for all efforts, but will be essential for some, depending upon the topic. The Enterprise Modelers and the System Architect will be required to discuss and work with information at the DOD SECRET level.

4.3.4 Proposal Preparation Costs

The cost of preparing proposals in response to the BAA shall not be an allowable cost under any resultant contract from these BAA's. This announcement does not commit the Government to pay for any response preparation cost. The cost of preparing proposals in response to the BAA is not considered an allowable direct charge to any other contract.

5. Administrative Information

5.1 Proposal Delivery

The deadline for receipt of proposals is 12:00 noon Eastern Daylight Time on Tuesday, May 18th, 1999. Mail or hand carry proposals to:

5.1.1 DARPA/ISO

5.1.1.1 BAA 99-18

Attn: Col McCorry
3701 North Fairfax Dr.
Arlington VA 22203-1714

The vast majority of the material submitted in response to this solicitation should be unclassified. However, offerors submitting classified material (up to DOD SECRET) should submit it in a separate enclosure from the remainder of their unclassified submission.

5.2 Proposal Information Repository

Information regarding this JFACC Project solicitation (BAA 99-18) is accessible via the WWW at http://www.darpa.mil/iso/jfacc . It is anticipated that the following information will be available on-line during the course of the solicitation:

- Commerce Business Daily (CBD) announcements for each solicitation.
- Proposers Information Package
- Relevant background material, as deemed necessary
- Announcements containing any new official information
- FAQ files containing answers to questions submitted for each solicitation.

5.3 Proposal Questions

Questions regarding any portion of this solicitation, as well as comments, are to be submitted via electronic mail to: baa99-18@darpa.mil. Responses will be made available as updates to the FAQ files available on the WWW at http://www.darpa.mil/iso/jfacc . See Section 3.4, "Key Dates and Milestones" for submission deadlines.

5.4 Briefing to Potential Proposers

On 20 April 1999, an unclassified informational briefing to potential proposers will be held from 0830 to 1230 at

Arlington Hilton Hotel (Ballston)
950 North Stafford Street
Arlington, VA 22203
Phone: (703) 528-6000

This briefing will cover project description and goals as well as background information. Seating is limited. Potential attendees must register with the government to attend the Briefing to Potential Proposers. To register, send an e-mail request to baa99-18@darpa.mil. The request should contain only the word "REGISTER" in the subject field. The request must contain a ranked, numbered list of requested attendees, with 1 (one) being the highest priority. The list should include each requested attendee's name, title, institution or company, institution department or company division, telephone, fax, and electronic mail address. Registration closes on 15 April 1999. If we cannot accommodate all the requests, we will use the rankings on your list to determine negative replies. Negative replies will be sent out no later than 16 April 1999.

5.5 Points of Contact

Technical Point Of Contact:

Col. Dan McCorry, DARPA, Information Systems Office, JFACC Program Manager, 3701 N. Fairfax Drive, Arlington, VA 22203, via electronic mail: baa99-18@darpa.mil.

Contracting/Costing Point Of Contact:

Ms. Algeria Tate, DARPA, Contracts Management Directorate (CMD), 3701 N. Fairfax Drive, Arlington, VA 22203-1714, via electronic mail: baa99-18@darpa.mil.